granular material whose composition had been measured by Viking 1 and 2. For comparison, it also gives the composition of subalkaline basalts from Reunion Island. The Martian and terrestrial rocks correspond completely.

In spite of the similarity of the rocks' compositions in widely separated regions of the Martian surface, we must consider the possibility that the microgranular dust coating may not have been brought in from very distant regions, but may be due to local erosion in the region under consideration. Thus a similar composition of rocks might be found if one were to investigate geomorphologically similar regions. In that case, the terrestrial analog of the bedrock investigated by Phobos 2 also basalt.

These are the first, preliminary results of analyzing the gamma spectrometric information obtained by Phobos 2. The information processing continues. It may prove possible to reveal a pronounced difference in the composition of the bedrock in different surface regions investigated Mars. However, detailed processing of all of the information obtained will require more time.

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Observations of electron and ion flux in the vicinity of Mars using the HARP spectrometer on Phobos 2

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The energy and angular distributions of electrons and ions in eight fixed directions within a solid angle $\sim 160 \times 20 \times 10°$ have been measured by Phobos 2. The angular resolution is $\sim 20°$ and the energy resolution is $\sim 10\%$. These measurements have revealed that electron energy distributions in the transition layer of the magnetosphere have two distinct maxima. Similar spectra have been observed in the plasma sheet in the areomagnetic tail.

In this paper we present preliminary results of measurements of electron and ion fluxes on 1 and 5 February 1989, using the HARP energy spectrometer on Phobos-2 on the first and second elliptical orbits of Mars (pericenter ~860 km, apocenter ~79,000 km).

The HARP differential hyperbolic analyzer made it possible to measure charged particles with energies $E/q \approx 0.2$-800 eV in the antisolar half-space. The analyzing field was varied in steps. The instrument's field of view (~160 × 20 × 10°) is symmetric relative to the antisolar direction. Within this field, particles were detected simultaneously in eight fixed directions (~20 × 10°) with ~20° angular resolution. The HARP instrument was specially developed for the Phobos project (Szucs et al., 1989; Kiraly et al., 1989). The operating principle of the analyzer was incorporated earlier into an instrument for investigating the earth's ionosphere (Shyn et al., 1976).

On the first and third elliptical orbits, the instrument's operating regime provided for the following: measurement of electrons with energies from ~3.4 to ~800 eV, 25 energy steps, ~25 sec measurement period (1 sec per step); measurement of ions with energies from ~0.25 to ~800 eV, 50 energy steps, ~50 sec mesurement period.

The energy and angular distributions of electrons and ions were recorded in turn, i.e., the length of a complete measurement cycle was ~75 sec. The frequency of measurements near the planet was 45 cycles/h.

In the present paper we devote most attention to electron measurements.

The integrated electron and ion fluxes (summed over energy and over all eight directions) detected during the first approach of the craft to the planet are presented in Fig. 1. From Fig. 1 it is seen that the flux intensity increased considerably near Mars. The abrupt rise in flux intensity corresponds to crossing the bow shock, the position of which agrees with measurements of the TAUS spectrometer (Rosenbauer et al., 1990). The subsequent decrease in plasma fluxes corresponds to crossing the magnetopause, the position of which was determined from ion measurements (Rosenbauer et al., 1990).

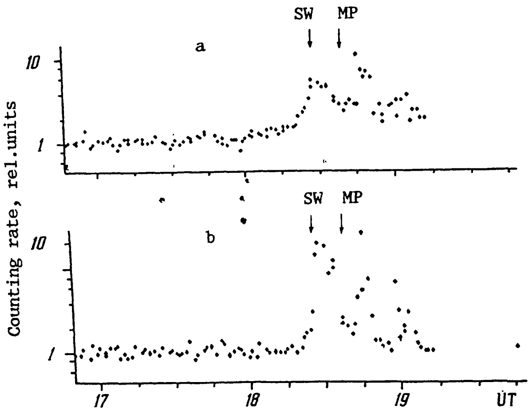

FIG. 1. Time variation of the total counting rate of electron flux (a) and ion flux (b) during the first approach of Phobos 2 to Mars (1 February 1989). SW and MP are the positions of the shock wave and magnetopause, respectively.

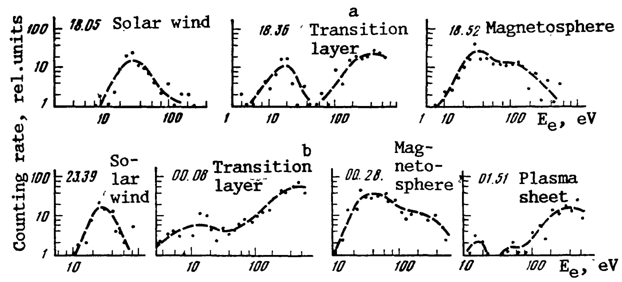

FIG. 3. Examples of energy spectra (counting rate as a function of energy) typical of different plasma regions near the planet and recorded by the HARP instrument on the first (a) and second (b) elliptical orbits of 1 and 5 February 1989, respectively.

The dynamics of the electron spectra recorded near the planet at a 56° angle to the sun—planet line may be traced from Fig. 2. It is seen that the initial spectra (the counting rate as a function of energy) correspond to the undisturbed solar wind, the parameters of which changed as the planet was approached: the electron density increased about 50% and the electron velocity decreased. The nature of the spectra then chaged sharply (almost discontinuously), the flux intensity and the maximum energy increased, the energy distribution widened considerably, and a second distinct maximum appeared. This jump obviously corresponds to the craft crossing the bow shock near the planet. The time of crossing the bow shock was 18^h20^mUT on 1 February and 23^h55^mUT on 4 February, or distances of ~1600 km and ~1800 km from the planet's surface at solar zenith angles of ~10° and ~11°, respectively. The precursors of the shock wave front, characterized by the appearance of more energetic electrons, corresponded to distances of ~2100 km and ~2400 km.

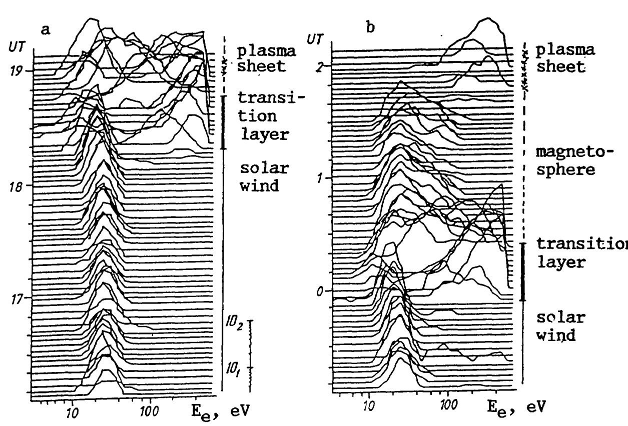

FIG. 2. Time variation of electron energy spectra (variation of the counting rate with energy) measured with the HARP instrument on the first (a) and second (b) elliptical orbits of Phobos 2 on 1 and 5 February 1989, respectively.

The bow shock crossing times that were determined from the variation of the electron energy spectra measured with the HARP instrument agree well with estimates based on data from the TAUS ion spectrometer (Rosenbauer et al., 1990). The measured changes in electron flux intensity and energy distribution behind the shock front indicate the existence of different plasma regions. The processes of interaction of the solar wind with Mars evidently differ from those for Earth and Venus. The terminology used to describe the various plasma regions in the vicinity of Earth and Venus may therefore not be entirely suitable for Mars. It is still premature to create any new definitions, however. In this paper we have designated the various regions with characteristic changes in the observed spectra (Fig. 2) using the terminology for Earth's magnetosphere. The data in Fig. 2 signify that the electron spectra observed in the vicinity of the planet's tail are similar to those immediately behind the bow shock. These spectra definitely show that electrons with energies higher than 100 eV are present behind the shock wave in the transition layer.

The most typical examples of spectra recorded in different regions of the Martian magnetosphere are shown in Fig. 3. It is seen that the distributions in the transition layer are not Maxwellian, and the maximum energies exceed the upper energy limit measured by the HARP instrument for the 56° direction in the antisolar half-space. The energy spectra have two distinct maxima.

The electron fluxes were more isotropic in the inner magnetosphere, and their energies were in the range ~10-200 eV for all eight directions. The energy distributions had a fairly broad maximum in the range from ~20 eV to ~150 eV. A two-peak structure could discerned most of the spectra.

In the plasma sheet located in the magnetospheric tail, in the planet's optical shadow, the electron energy distributions were the same as those observed in the transition layer, as noted earlier. As the tail was approached, strong fluctuations in the electron flux intensity, which sometimes decreased to zero, were observed.

Measurements of the electron energy spectra along the orbit show that abrupt changes in the type of distribution correspond to crossing of the bow shock, the magnetopause, and the plasma sheet, the boundaries of which coincided with those measured in the TAUS experiment (Resenbauer et al., 1990). The similarity between the electron spectra measured in the transition layer and the plasma sheet may result from the fact that these regions are adjacent to each other. The existence of a plasma sheet containing accelerated electron fluxes in the interior of the Martian magnetosphere was first detected in the HARP experiment.

The physical mechanisms responsible for electron acceleration behind the bow shock and the appearance of bimodal energy distributions are not yet known. We can assume, however, that future analysis of our data in conjunction with their detailed comparison with the results of other plasma and magnetic experiments on the Phobos craft, as well as with earlier observations (Gringauz, 1981), will considerably improve our understanding of the physical nature of the plasma around Mars.

*Deceased.

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First measurements of ions of Martian origin and observation of a plasma layer in the magnetosphere of Mars: the TAUS experiment on the spacecraft Phobos 2

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On the spacecraft Phobos 2 the TAUS instrument was used to measure detailed energy and angular spectra of ions entering a 40°×40° solid angle in the direction of the sun. These measurements, confirming previous results from the satellites Mars 2, 3, and 5 (see e.g., Gringauz *et al*. (1976), Gringauz (1976, 1981), and Dolginov *et al*. (1976)), are also the first plasma measurements deep in the optical shadow of the planet; mass spectrometry of ions in near-Martian space had not been carried out previously. As a result of these measurements, it was observed that the Martian magnetosphere is to a significant degree filled with fluxes of heavy ions, originating in the atmosphere of the planet, and that there is a plasma layer in the areomagnetic tail, also consisting mainly of heavy ions. The flux of planetary ions leaving Mars through the areomagnetic tail is tentatively estimated to be $(0.5–2)\cdot 10^{25}\text{sec}^{-1}$.

The analysis of ions with respect to energy E_i (i = 1, ..., 32) in the TAUS experimental was carried out using a hemispherical electrostatic analyzer with energy resolution in the energy/charge range 30 eV/q ≤ E_i/q ≤ 6 keV/q. Using a similar electrostatic analyzer installed behind it, which had a variable accelerating potential U_a, all ions passed through with fixed energy $E_i + qU_a \approx 6$ keV. Protons, α particles, and heavier ions ($m_i/q \geq 3$) were separated using a magnetic system located in the middle of this analyzer.

In the TAUS experiment, for each value of E_i, we simultaneously used individual scintillation detectors to measure the flux of protons (or α particles) in eight azimuthal directions ϕ_j (j = 1, ..., 8) for a three-axis orientation of the spacecraft, and the flux of heavy ions arriving within the range $\phi_j \approx \pm 20°$. Scanning over the angles ϑ_k(k = 1, ..., 8) was done using an electrostatic deflector located in front of the first analyzer. In most operating modes, the ion integration time was approximately 24 msec. The three-dimensional (E_i, ϕ_j, ϑ_k) spectrum of protons and α particles, consisting of 2048 measurements, and the two-dimensional (E_i, ϕ_j) spectrum of heavy ions were measured in 8 sec.

In connection with the limited telemetry bandwidth of the spacecraft, a microprocessor in the TAUS instrument implemented a data compression scheme. Summing over (j, k), (i, k), or (i, j), the multidimensional ion spectra were reduced to one-dimensional energy (i = 1, ..., 32) and angular (j, k, = 1, ..., 8) spectra. Moreover, from the three-dimensional ion spectra we calculated their zeroth (density), first (velocity vector), and second (six components of the pressure tensor) moments. The relationship between the quantities of transmitted three-, two-, and one-dimensional spectra and their moments varied as a function of the operating mode of the spacecraft telemetry system (fast ≈200 bits/sec, slow ≈10 bits/sec for TAUS),

